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Is breastfeeding associated with later child eating behaviours?

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Abstract

Individual differences in children's eating behaviours emerge early. We examined the relationship between breastfeeding exposure and subsequent eating behaviours among children from the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort. Children (n = 970) were grouped according to their breastfeeding exposure: high (full breastfeeding ≥ 4 months with continued breastfeeding ≥ 6 months), low (any breastfeeding < 3 months or no breastfeeding) and intermediate (between low and high breastfeeding categories). Aspects of eating behaviour from ages 15 months to 6 years were captured using a combination of maternal reports (Child Eating Behaviour Questionnaire; Infant Feeding Questionnaire; Preschooler Feeding Questionnaire) and laboratory-based measures of meal size, oral processing behaviours (e.g. average eating speed and bite size) and tendency to eat in the absence of hunger. Most children had low (44%) or intermediate (44%) breastfeeding exposure; only 12% had high exposure. After adjusting for confounders, multivariable linear regression analyses indicated the high (but not intermediate) breastfeeding group was associated with significantly lower reported food fussiness at 3 years compared to low breastfeeding group (-0.38 [-0.70, -0.06]), with similar but non-significant trends observed at 6 years (-0.27 [-0.66, 0.11]). At 3 years, mothers in the high breastfeeding group also reported the least difficulty in child feeding compared to low breastfeeding group (-0.22 [-0.43, -0.01]). However, high breastfeeding was not associated with any other maternal-reports of child feeding or eating behaviours, and no significant associations were observed between breastfeeding exposure and any of the laboratory measures of eating behaviour at any of the time points. These results do not strongly support the view that increased breastfeeding exposure alone has lasting and consistent associations with eating behaviours in early childhood.

Keywords:

Breastfeeding; Child eating behaviours; Oral processing; Satiety responsiveness: Food fussiness

Abbreviations:

AGA, appropriate for gestational age; BF, Breastfeeding; CEBQ, Child Eating Behavioural Questionnaire; EAH, Eating in the Absence of Hunger; IFQ, Infant Feeding Questionnaire; LGA, large for gestational age; PFQ, Preschooler Feeding Questionnaire; SGA, small for gestational age.

1. Introduction

Early childhood is an important period for establishing eating behaviours that underpin good nutrition and healthy growth (WHO, 2016). Behaviours such as a slower eating speed (Berkowitz et al., 2010; Fogel et al., 2017b), responsivity to satiety cues (Carnell, Benson, Gibson, Mais, & Warkentin, 2017) and consumption of a variety of fruits and vegetables (Boeing et al., 2012) have been associated with later weight outcomes in childhood, with individual differences in these behaviours emerging early and shaped in part by the feeding environment (Kral et al., 2018). As breastfeeding is the first type of feeding that many infants are exposed to, it is suggested to be an early target for promoting healthier eating behaviours from a young age (Taveras et al., 2004).

There are several pathways through which breastfeeding has been hypothesised to influence a child's eating behaviour. First, the sensory experience of human breastmilk might shape early food preferences through flavour learning (Mennella, 2014). A variety of tastes and flavour volatiles ingested by the mother during pregnancy are transmitted to the foetus via the amniotic fluid, which continues postpartum through breastmilk feeding to the infant (Mennella, 2014; Mennella & Trabulsi, 2012). Randomised studies have reported that infants are more accepting of a carrot-flavoured food during weaning if their mother consumed carrot juice whilst breastfeeding, compared to infants whose mothers consumed water (Mennella & Beauchamp, 1999; Mennella, Daniels, & Reiter, 2017; Mennella, Jagnow, & Beauchamp, 2001). Others have found breastfed infants are more rapid in their acceptance of novel foods and flavours compared to those who are formula fed (Maier, Chabanet, Schaal, Leathwood, & Issanchou, 2008), and continue to accept a wider variety of vegetables at age 15 months, 3 and 6 years (Maier-Nöth, Schaal, Leathwood, & Issanchou, 2016) and reported to be less fussy at age 7 years (Galloway, Lee, & Birch, 2003). This suggests an important role of breastmilk feeding in the development of children's early food preferences and acceptance beyond specific flavour learning (Forestell & Mennella, 2007; Hausner, Nicklaus, Issanchou, Mølgaard, & Møller, 2010; Sullivan & Birch, 1994).

Compositional features of breastmilk have also been linked to the development of appetite control mechanisms in infancy. Unlike formula milk, breastmilk changes in composition from one feed to another and across the lactation period (Ballard & Morrow, 2013). Breastfed infants may therefore have more opportunity to adapt nutrient intake in response to a fluctuating macronutrient content (Mitoulas et al., 2007; Woolridge, Ingram, & Baum, 1990) and appetite-related hormones present in human

breastmilk (Ballard & Morrow, 2013; Newburg, Woo, & Morrow, 2010; Savino & Liguori, 2008). Additionally, the act of breastfeeding is reported to encourage a more responsive and less controlling feeding style in mothers (Blissett & Farrow, 2007; Farrow & Blissett, 2006; Taveras et al., 2004), which may promote eating self-regulation through mothers being more aware of their child's satiety cues and infants gaining more control over their own feeding times and the volume of milk they are exposed to. In support, longer breastfeeding duration has been associated with increased parent reported satiety responsivity in toddlers (Brown & Lee, 2012) and a lesser tendency to eat in the absence of hunger in adolescents (Reyes et al., 2014), suggesting that breastfeeding experience might impact children's appetite regulation beyond the breastfeeding period.

Despite the multiple pathways through which breastfeeding may impact children's eating behaviour, consistent evidence to support an enduring relationship between breastfeeding exposure and eating behaviours later in childhood is still lacking, particularly for the proposed link to eating behaviours thought to represent better self-regulation of energy intake. To address this, we examined the relationship between breastfeeding duration and a variety of child eating behaviours, captured as a combination of maternal-reports and laboratory-based measures assessed between ages 15 months and 6 years in the multi-ethnic Growing Up in Singapore Towards healthy Outcomes (GUSTO) study. Faster eating and the tendency to snack in the absence of hunger are two behaviours that have been consistently associated with increased energy intake in a laboratory meal setting in the GUSTO cohort (Fogel et al., 2017b; Fogel, McCrickerd, et al., 2018). Faster eating was also associated with higher BMI and adiposity at 4.5 years (Fogel et al., 2017b) and mothers' reports of lower satiety responsivity at 6 years (Fogel, Fries, et al., 2018). If breastfeeding experience supports the development of eating behaviours in this cohort, we expect that children with greater exposure to breastfeeding might be less fussy in their eating styles, but also exhibit eating behaviours that support better energy intake regulation, such as higher satiety responsivity, slower eating, smaller meal size and less eating in the absence of hunger. Evaluating the link between breastfeeding and a variety of eating behaviours within the same cohort should help clarify whether public health advice to increase breastfeeding exposure can optimise the development of eating behaviours in early childhood.

2. Methods

2.1 Study design and population

In 2009-2010, women in their first trimester of pregnancy were recruited from the maternity units of two major Singaporean public hospitals, KK Women's and Children's Hospital and the National University Hospital. Women were eligible to join the "Growing Up in Singapore Toward healthy Outcomes" (GUSTO) study if they were of Chinese, Malay or Indian ethnicity with homogenous parental ethnic background, between 18-46 years old, not diagnosed with type I diabetes mellitus and not on any psychotropic medications or undergoing chemotherapy. Details of the cohort (n = 1247) have been published previously (Soh et al., 2014). Written informed consent was obtained from all participants, and the study (NCT01174875; https://clinicaltrials.gov/) was granted ethical approval by both the National Healthcare Group Domain Specific Review Board and SingHealth Centralized Institutional Review Board.

A flow chart of participants included in the current study is presented in Figure 1. Only singleton children born at term (≥37 weeks gestation) with information on breastmilk feeding exposure were considered as eligible participants for this study (n = 970). Children were included based on the availability of eating behaviour data from ages 15 months to 6 years. Restricted visit time availability meant that only a subset participated in the eating behaviour tasks conducted at 4.5 and 6 years (see Fogel, McCrickerd, et al., 2018). The final sample sizes considered for data analyses across the various tasks are shown in Figure 1.

2.2 Participant characteristics

Participant baseline characteristics, including educational attainment, maternal age, ethnicity and family history of atopy, were collected during the first trimester of pregnancy through interviewer-administered questionnaires. Maternal pre-pregnancy BMI (kg/m^2) was derived from maternal height measured at 26-28 weeks gestation (using SECA 213 Stadiometer) and pre-pregnancy weight reported by the women at 11-14 weeks gestation. Information on child sex, parity and birth weight was extracted from medical records. Infants were classified into birth-weight-for-gestational-age percentiles according to the method described by Mikolajczyk et al. (Mikolajczyk et al., 2011), and infants who were $<10^{th}$ percentile were considered small-for-gestational-age (SGA), 10-90^{th} percentile were appropriate-for-gestational-age (AGA), and $>90^{th}$ percentile were large-for-gestational-age (LGA). Child's weight and length/height were measured at 12 months and 4, 5 and 6 years using a SECA 334 (12 months) or SECA 803 Weighing Scale (4-6 years), and a SECA 210 Mobile Measuring Mat (12 months) or SECA stadiometer

213 (4-6 years). Child BMI z-scores were derived using an R macro provided by the World Health Organization (WHO, 2006).

2.3 Breastfeeding exposure

Using interviewer-administered questionnaires, breastfeeding practices, including whether the child was still breastfed and to what extent, were captured as 'exclusive', 'predominant', 'partial' breastfeeding or 'formula feeding', based on WHO breastfeeding definitions (WHO, 2008; WHO/UNICEF, 1993). The questionnaire was conducted with each mother at every postnatal visit starting from week 3, then at 3-monthly intervals from month 3 to month 18 (when mothers were asked to record responses for every month within the 3-month interval between visits), and then yearly intervals from year 2 to year 4.

Full breastfeeding was initially defined as exclusive or predominant breastfeeding at each time point (Pang et al., 2016), and this was used to categorise children as having experienced 'low', 'intermediate' or 'high' breastfeeding exposure according to previously defined criteria (Cai et al., 2015). High-breastfeeding infants were those fully breastfed for 4 months who continued to breastfeed at least partially until at least 6 months. Intermediate-breastfeeding infants were breastfed at least partially beyond 3 months but did not meet the criteria for high breastfeeding. Low-breastfeeding infants were weaned from breastmilk or exclusively formula-fed before the age of 3 months. Based on these definitions, breastfeeding exposure includes infants who were both fed at the breast and through expressed breastmilk.

2.4 Outcome measures: Children's eating behaviours

2.4.1 Maternal-reports of feeding practices and child eating behaviours at 15 months, 3 and 6 years

Three established parent-report questionnaires assessing aspects of maternal feeding beliefs and practices and child eating behaviours were administered at different ages: the Infant Feeding Questionnaire (IFQ; Baughcum et al., 2001), the Preschooler Feeding Questionnaire (PFQ; Baughcum et al., 2001), and the Children's Eating Behaviour Questionnaire (CEBQ; Wardle, Guthrie, Sanderson, & Rapoport, 2001). All questionnaires were completed by the mothers. To focus the study outcomes, only subscales that were measured at multiple time points and specifically related to aspects of children's food fussiness, acceptance of new foods, satiety responsivity and tendency towards overeating were included.

The IFQ was completed when the children were 15 months old. The IFQ has seven subscales used to assess a mother's feeding beliefs and practices. Previous validation of the IFQ in the GUSTO cohort has shown a moderately good fit with the original 7-subscale structure hence the original classification of the items in the IFQ was mostly adopted (Quah et al., 2016). Two subscales (*Awareness of infant's hunger and satiety cues* and *Concern about infant overeating or becoming overweight*) were analysed. The scores for each subscale, captured as the averages of their item scores, were used as outcome variables.

The PFQ was completed when the children were 3 years old. Of the eight PFQ subscales, two (*Difficulty in child feeding* and *Concern about child overeating or being overweight*) were analysed. Subscale scores, averaged from item scores contributing to the subscale, were used as outcome variables in the analyses.

Mothers also completed the CEBQ when the children were 3 and 6 years old. The CEBQ captures eight parent-reported appetitive traits, which can be broadly categorized as either food-approach and food-avoidance behaviours (Wardle et al., 2001) and has been validated in the GUSTO cohort (Quah et al., 2017; Quah et al., 2019); of the revised subscales suitable for this cohort, *Satiety responsiveness* and *Food fussiness* were included in the current analyses using z-scores generated by Quah et al. as outcome variables.

2.4.2 Observed eating behaviours at ages 4.5 and 6 years

In addition to maternal reports, several observed eating behaviours were assessed during *ad libitum* lunches served at both 4.5 and 6 years of age. The procedures for these meal observations have been published in detail elsewhere (Fogel et al., 2017a; Fogel, McCrickerd, et al., 2018). The children were fasted for a minimum of three hours before each lunch session, which took place in the same test room at both time points and contained child-appropriate furniture and utensils. The sessions were recorded with three high-resolution CCTV cameras positioned to capture the child's behaviour from multiple angles. The mother was present in the room during the 4.5-year visit and was requested to interact with her child as normal but not to interfere with the child's food choices or intake. Mothers were not present in the lunch room at the 6-year time point.

2.4.2.1 Ad libitum Energy intake

During the lunch session, children were served an *ad libitum* meal consisting of foods and drinks selected to be familiar and relatively well-liked, based on responses to a Food Frequency Questionnaire (FFQ) collected at an earlier time point. At 4.5 years, children were served a buffet-style lunch consisting of 9 foods and 3 drinks: white bread (Gardenia; 2.63 kcal/g; 6 slices), pancakes (Aunty Jemima; 3 kcal/g; 70 g), Honey Stars cereal (Nestle; 3.8 kcal/g; 80 g), chocolate cake (Sara Lee; 4.3 kcal/g; 80 g), cheese (Cowhead; 2.95 kcal/g; 66 g), chicken nuggets (CP; 2.29 kcal/ g; 216 g), chicken cocktail sausage (Fairprice; 2.95 kcal/g; 192 g), apple slices (0.44 kcal/g, 204 g), canned corn (Hosen; 0.81 kcal/g; 160 g), apple juice (Marigold; 0.5 kcal/ml; 6 boxes), full cream milk (Marigold; 0.65 kcal/ml; 6 boxes) and water. At 6 years, children were presented with a self-served meal consisting of vegetarian fried rice (800 g; 1.86 kcal/g) and water.

At both time points, children were instructed to serve themselves from the portions provided and eat as much as they liked for their lunch. Additional portions of all the foods were provided by the research staff if any were completely consumed. Children consumed their lunch within 30 minutes and rated their hunger/fullness before and after lunch using a similar five-point picture rating scale ranging from 'Hungry' to 'Very full' at 4.5 years and 'Very hungry' to 'Very full' at 6 years. The foods, including any leftovers, were weighed before and after consumption using a balance accurate to 0.1 g and this was used to estimate energy consumed during lunch (Fogel, McCrickerd, et al., 2018).

2.4.2.2 Eating rate and oral processing behaviours

Children's eating rate and oral processing behaviours during lunch were determined by coding the CCTV videos using behavioural annotation software ELAN (version 4.9.1, Max Planck Institute for Psycholinguistics, The Netherlands), in combination with an established coding scheme (Fogel et al., 2017a). The frequency of each bite, chew and swallow taken throughout the meal was recorded and used to determine the total time (in sec) spent with food in the mouth (total oral exposure time) and without (inter-bite interval). This was then combined with the weight of the foods consumed during the meal to derive the average eating rate (g/min), bite size (g/bite), chews per gram and total meal duration (min) for each of the meals. The video-coding was performed by a single trained coder. A random 10% of the videos within each time point were validated by a second trained coder and showed excellent inter-rater reliability (intra-class correlation coefficients were 0.954 and 0.995 at 4.5 and 6 years, respectively). Among all children who participated in the lunch session at year 6, we excluded

from the analyses children who had insufficient oral processing data due to very short mealtimes (n = 43).

2.4.2.3 Eating in the absence of hunger (EAH)

Children completed an EAH task at both 4.5 and 6 years, following a 'free access' protocol adapted from Fisher & Birch (2002), approximately 10 minutes after lunch was cleared. Children were provided with colouring paper and crayons and encouraged to play by the researcher. After 5 minutes, the researcher placed two sweet (M&M: 18 units, 4.83 kcal/g; Hello Panda: 10 units, 5.43 kcal/g) and two savoury (Rollercoster: 10 units, 5.55 kcal/g; Want Want; 2 units 4.83 kcal/g) snacks separately in small bowls on the table within the child's reach, and informed the child that the researcher would be leaving the room to prepare the next activity and that he or she could have the snacks if they wished. The researcher returned after 5 minutes and collected the bowls before taking the child to the next task. The snacks were weighed before and after to estimate energy intake.

Among the children who completed the EAH tasks, those who consumed < 50g of food at lunch and indicated that they were still hungry afterwards were excluded from statistical analyses. This approach is in line with previous works (Fisher & Birch, 2002; Fogel, Fries, et al., 2018), as the absence of hunger could not be assumed for these children (n = 82 at 4.5 years and n = 108 at 6 years).

2.5 Statistical analyses

Statistical analyses for this study was prespecified to examine the association of breastfeeding exposure (low, intermediate or high breastfeeding) with children's eating behaviours from maternal-report questionnaires, and with energy intake, eating rate and the oral processing behaviours derived from the lunch tasks using multivariable linear regression. As some children did not eat in the absence of hunger during the EAH task, children were categorized as 'No' vs 'Yes' for EAH; logistic regression was used to examine the relationship between breastfeeding and EAH. For all adjusted models, we selected confounders based on previous publications (Brown & Lee, 2012; de Barse et al., 2017), and included maternal age (years), ethnicity (Chinese, Malay, Indian), maternal education (secondary and below, technical school or tertiary), maternal pre-pregnancy BMI (kg/m^2), child sex and birth weight category (small for gestational age (SGA), appropriate for gestational age (AGA), large for gestational age (LGA)). For the EAH tasks, models were also adjusted for energy intake (kcal) during the lunch task that preceded it.

Several sensitivity analyses were performed, some of which are provided as supplemental material. First, we explored the effect of additional adjustment for parity (primiparous, multiparous) and family history of allergy (yes, no) for outcomes related to food fussiness (de Barse et al., 2017), and results are presented in Supplementary Table 2. Second, as the error residuals of the observed eating behaviour variables at 4.5 and 6 years were not normally distributed, we log-transformed these outcome variables; similar results were obtained (results not shown). Third, we examined the reproducibility of results among children who had a complete set of eating behaviour outcomes across all time points, *i.e.* from 15 months to 6 years of age (n = 109; see Supplementary Table 3). All patterns of data were the same. Finally, we examined whether ethnicity or child sex modified the association of breastfeeding and eating behaviours by including interaction terms in the regression analyses; there appears to be no significant modification effect with all *p*-interaction ≥ 0.08 (see Supplementary Table 5). Adjustment for multiple comparisons was not performed as it increases the type II error for the associations that are not null (Rothman, 1990). Participants (0-8.7%) with missing covariates were excluded from the statistical analyses. All statistical analyses were performed using IBM SPSS (Version 25).

3. Results

3.1 Study and participant characteristics

Participant characteristics (overall and by breastfeeding exposure group) are summarized in Table 1. The majority of study children had either low or intermediate exposure to breastfeeding during infancy (44.3% and 43.5%, respectively); only 12.2% had high breastfeeding exposure. Mothers who were younger, of Malay ethnicity, with lower educational attainment or with higher pre-pregnancy BMI were more likely to be in the low breastfeeding group. Child BMI Z-scores from 1 to 6 years were similar across the different breastfeeding exposure groups.

As differing numbers of participants were included in the analyses for various eating behaviour tasks and questionnaires, we examined participant characteristics for each subset (Supplementary Table 1). We found no significant differences among participants who were included and excluded for the year 4.5 lunch task analyses, or among those with or without a complete set of outcome data. However, mothers who were not included in the month 15 IFQ analyses were significantly younger and of Malay ethnicity, with a lower proportion of Chinese ethnicity. For year 3 CEBQ analyses, a larger proportion of Chinese and a lower proportion of Malay mothers were excluded from the analyses compared to those included.

Similarly, more Chinese and less Malay mothers, and those with lower BMI were excluded from the year 6 CEBQ analyses. For year 6 lunch tasks, younger and a larger proportion of Indian mothers were not included in the analyses.

3.2 Maternal-reported child feeding and eating behaviours at 15 months and 3 and 6 years

The unadjusted mean (±SD) and adjusted mean differences in maternal reports of child feeding and eating behaviours across the breastfeeding exposure groups are shown in Table 2 (additional regression details are shown in Supplementary Table 4). Compared to mothers in the low breastfeeding group, those in the intermediate breastfeeding group reported greater awareness of their infant's hunger and satiety cues at 15 months and were least concerned with their child overeating/being overweight at 3 years old. However, the same trends were not seen in the higher breastfeeding group, nor were there any differences in reported concern of infant overeating/overweight between breastfeeding exposure groups at the earlier time point. At 3 years, mothers in the high breastfeeding group reported less difficulty in child feeding than those in the low breastfeeding group. This association became statistically non-significant with further adjustment for parity and family history of allergy, although its direction was similar (see Supplementary Table 2).

We found no significant associations between breastfeeding exposure and the CEBQ measure of satiety responsiveness at 3 or 6 years (Table 2). However, children in the high breastfeeding group had significantly lower levels of reported food fussiness at 3 years than those in the low breastfeeding group; this trend was weaker and no longer significant at age 6 years (see Table 2). Similar differences in reported food fussiness seen at both 3 and 6 years remained after further adjustment for parity and family history of allergy in the additional sensitivity analysis but were no longer statistically significant (Supplementary Table 2).

3.3 Observed eating behaviours

The unadjusted mean (±SD) and adjusted mean differences in observed laboratory-based eating behaviours are also presented in Table 2. Across children exposed to different levels of breastfeeding, we found no significant differences in oral processing behaviours, energy consumed during lunch or tendency to EAH at ages 4.5 or 6 years.

4. Discussion

Early childhood is an important period for establishing children's eating behaviours. Breastfeeding has been hypothesized to support the development of food preferences and appetite control mechanisms during this period through several pathways. Our data from the GUSTO cohort show only a few associations between breastfeeding exposure during infancy and a variety of maternal-reports of child feeding and laboratory-based measures of eating behaviours captured during the preschool years. These findings thus do not strongly support the view that increased breastfeeding exposure alone is likely to confer a substantial advantage to children's health through lasting and consistent associations with eating behaviours in childhood.

Aspects of children's eating behaviours were captured using a combination of maternal reports and objective measures of laboratory-based food intake. Across these measures, maternal reports of food fussiness (CEBQ) and difficulty in child feeding (PFQ) were the only variables to show consistent links with prior breastfeeding exposure. The highest exposure to breastfeeding was significantly associated with less food fussiness when the children were 3 years old, with similar but non-significant differences observed when the children were 6 years old. This is consistent with previous studies linking longer breastfeeding duration with less food fussiness at age 7 (Galloway et al., 2003) and increased acceptance of a variety of foods during the preschool years (Forestell & Mennella, 2007; Hausner, Nicklaus, Issanchou, Molgaard, & Moller, 2010; Maier et al., 2008). However, relationships were weakened after age 3 years in the current cohort and further attenuated after accounting for parity, suggesting that the positive effect of increased breastfeeding exposure on ease of feeding and food fussiness may be overridden over time within the family environment. For the majority of children, a developmentally appropriate phase of fussy or picky eating tends to peak around 3 years (Cardona Cano et al., 2015), and it is possible that any influence of prior breastfeeding exposure may also be strongest within this timeframe.

Despite some consistency in the trend for maternal reports of food fussiness, there were no other consistent links between increasing breastfeeding exposure and maternal reports of awareness of satiety cues, concerns about overeating or later satiety responsivity. The few other studies assessing the link between breastfeeding exposure and parent reports of eating behaviours also lack in consistency. For example, Brown and Lee (2012) reported better CEBQ-reported satiety responsiveness among 18-24 month-old children who were breastfed for longer. By contrast, Rogers and Blissett (2017) reported that longer breastfeeding duration was not significantly associated with CEBQ-reported satiety

responsiveness or food fussiness at 12 months. Several factors could explain these mixed findings. First, studies have differed in their definition of breastfeeding exposure; some examined breastfeeding duration and exclusivity separately in relation to eating behaviours (e.g. Brown & Lee, 2012), while others examined breastfeeding exclusivity for different duration (e.g. Rogers & Blissett, 2017) and we integrated both the duration and exclusivity of breastfeeding when assessing associations with child eating behaviours. Finally, this research spans a variety of ages, from as young as age 12 months (e.g. Rogers & Blissett, 2017) to 6 years in our study. The interpretation of a child's behaviour captured in parent-report measures such as the CEBQ may be more stable in older children (Quah et al., 2019). When children are younger, such as 12 and 15 months, these measures may be more indicative of maternal behaviours and feeding practices than the child's eating behaviours *per se*.

Our direct observations of children's eating behaviours at 4.5 and 6 years arguably provide more objective measures than those captured in maternal-report questionnaires. Faster eating speed, energy intake at a meal and the tendency to eat in the absence of hunger have been identified as behavioural markers of children's eating self-regulation (Kral et al., 2018) and satiety responsivity (Carnell & Wardle, 2007). In the GUSTO cohort, faster eating speed (characterized by larger bite sizes and less chewing) has been shown to predict increased energy intake at a meal, child adiposity and weaker satiety responsiveness as reported by the mother (Fogel, Fries, et al., 2018; Fogel et al., 2017a). Similarly, higher levels of EAH at 4.5 years predicted increased EAH, larger portion selection and increased energy intake at 6 years in the same cohort of children (Fogel, McCrickerd, et al., 2018). However, we found no significant association of breastfeeding exposure with eating behaviours at age 4.5 and 6 years, nor a consistent trend with child BMI from age 4 to 6 years (Table 1). By contrast, the one previous study linking breastfeeding exposure to later observations of self-regulatory eating behaviours reported that shorter breastfeeding duration was associated with an increased likelihood of reporting hunger after a meal and EAH by 16-17 year old Chilean adolescents (Reyes et al., 2014). Methodological differences, such as the ages at which eating behaviours were measured, a limited overlap in the specific eating behaviours captured and socio-cultural variations between Asian young children and Chilean adolescents, may contribute to these different findings. Taken together, these data highlight that more longitudinal evidence is required to better understand and characterise the impact, if any, of breastfeeding exposure on later child eating behaviour.

Strengths of our study include its longitudinal nature, with various aspects of children's eating behaviours captured over time, particularly those related to energy intake control. Statistical models were also adequately adjusted for, with information collected on relevant confounders. However, there are some limitations to the current study that may restrict the conclusions drawn. Firstly, not all mothers and children were included in all the measures at every time point. Where possible, sensitivity analyses were conducted to corroborate the study findings and account for the variable participant numbers. Another important consideration is that our measure of breastfeeding exposure included infants who were fed expressed breastmilk from a bottle, and therefore we cannot discern the effects of the different modes of breastmilk feeding (i.e. infants fed at the breast vs those fed breastmilk by the bottle) on subsequent eating behaviours. It is possible that the self-regulatory characteristics of eating behaviour, such as satiety responsivity and eating speed, may relate less to the duration of breastmilk exposure and more to the mode of breastmilk feeding, as suggested by previous studies (Disantis, Collins, Fisher, & Davey, 2011; Li, Fein, & Grummer-Strawn, 2010; Ventura & Hernandez, 2019). Small sample sizes in the GUSTO cohort meant that the mode of breastmilk feeding on children's ability to self-regulate food intake could not be concurrently explored in the current dataset, however this will be considered independently in future work. More research is required to understand the interplay between breastfeeding duration and the mode of breastmilk feeding, and their links to subsequent parental feeding practices and child eating behaviours.

In conclusion, our results suggest that greater exposure to breastfeeding during infancy is not strongly associated with eating behaviours linked to energy intake regulation in childhood, but showed some small associations with increased maternal reports of food fussiness in the preschool years. Despite its other documented health benefits, greater breastfeeding exposure seems unlikely to have a major impact on later eating behaviours in childhood.

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Conflict of Interest Disclosures

KMG, LPS, CGF and Y-SC have received reimbursement for speaking at conferences sponsored by companies selling nutritional products. KMG, S-YC and Y-SC are part of an academic consortium that has received research funding from Abbott Nutrition, Nestec and Danone. CGF currently serves on the scientific advisory council for Kerry Taste and Nutrition. The other authors have no financial or personal conflict of interest to declare.

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Y-SC, KMG, FY, KHT, S-YC, LPS, MJM, JGE designed and led the GUSTO study; MSK, Y-SC, WWP conceptualized and designed the current study; DF, WWP, MCC, SBL, AF, KM, IMA, WLY conducted research; WWP, AF, KM, IMA, WLY, PLQ provided essential data; WWP performed statistical analysis; WWP, KM wrote the first draft of manuscript; MSK, S-YC, KMG, AF, IMA, WLY, PLQ, MEW, JGE, CGF, MCFF critically reviewed the manuscript. All authors read and approved the final manuscript; WWP and KM had primary responsibilities for final content.

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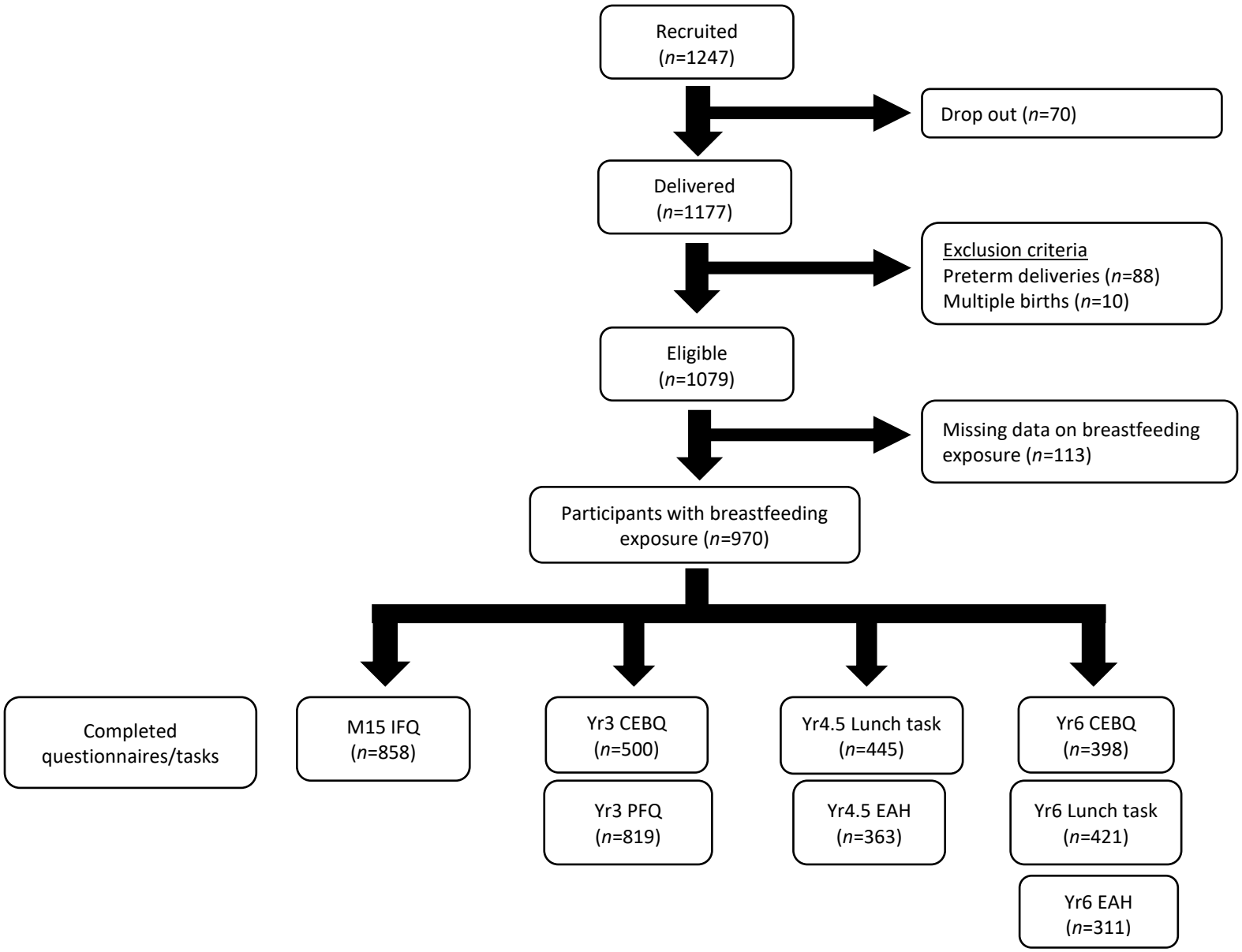

Figure 1. Flowchart of participants included in the current analyses.

Table 1. Mother-child characteristics among participants with data on breastfeeding (BF) exposure.

Participant characteristics	ALL participants (n=970)	Participants with data on breastfeeding exposure (n=970)		
		BF low (n=430, 44.3%)	BF intermediate (n=422, 43.5%)	BF high (n=118, 12.2%)
Maternal age (yr)[a]	30.8 ± 5.1	29.6 ± 5.5	31.8 ± 4.7	31.3 ± 4.3
Ethnicity[c]				
Chinese	558 (57.5)	206 (47.9)	262 (62.1)	90 (76.3)
Malay	239 (24.6)	146 (34.0)	85 (20.1)	8 (6.8)
Indian	172 (17.7)	77 (17.9)	75 (17.8)	20 (16.9)
Maternal education[c]				
Secondary and below	285 (29.4)	192 (44.7)	76 (18.0)	17 (14.4)
Technical school	330 (34.0)	171 (39.8)	138 (32.7)	21 (17.8)
Tertiary	344 (35.5)	62 (14.4)	205 (48.6)	77 (65.3)
Maternal pre-pregnancy BMI (kg/m^2)[a,c]	22.7 ± 4.4	23.4 ± 5.1	22.3 ± 3.8	21.7 ± 3.1
Child sex				
Female	465 (47.9)	210 (48.8)	197 (46.7)	58 (49.2)
Parity				
Primiparous	441 (45.5)	197 (45.8)	195 (46.2)	49 (41.5)
Family history of allergy[c]				
Yes	343 (49.9)	155 (50.0)	137 (47.2)	51 (58.6)
Child birth weight category[c]				
SGA	122 (12.6)	64 (14.9)	46 (10.9)	12 (10.2)
AGA	683 (70.4)	293 (68.1)	301 (71.3)	89 (75.4)
LGA	158 (16.3)	68 (15.8)	73 (17.3)	17 (14.4)
Child BMI Z-scores at 12 months[b,c]	-0.17 (-0.82, 0.51)	-0.07 (-0.83, 0.65)	-0.24 (-0.79, 0.39)	-0.19 (-0.92, 0.62)
Child BMI Z-scores at 4 years[b,c]	-0.02 (-0.61, 0.70)	0.08 (-0.58, 0.89)	-0.10 (-0.64, 0.55)	0.00 (-0.64, 0.68)
Child BMI Z-scores at 5 years[b,c]	-0.09 (-0.78, 0.67)	0.04 (-0.78, 0.87)	-0.20 (-0.81, 0.53)	-0.21 (-0.74, 0.51)
Child BMI Z-scores at 6 years[b,c]	-0.18 (-0.91, 0.63)	-0.11 (-0.95, 0.85)	-0.25 (-0.91, 0.49)	-0.06 (-0.81, 0.61)
Duration of any breastfeeding (months)[b,c]	3.4 (0.8, 9.2)	0.7 (0.3, 1.1)	6.8 (4.0, 11.9)	14.4 (11.8, 21.0)
Duration of full breastfeeding (months) [b,c]	0.5 (0.5, 0.5)	0.5 (0.5, 0.5)	0.5 (0.5, 0.5)	6.0 (5.0, 6.0)

Values presented are number of participants (percentage) unless otherwise indicated.

[a]Values are mean ± SD

[b]Values are median (IQR)

[c]Number of participants with missing data: Ethnicity (n=1); Maternal education (n=11); Maternal pre-pregnancy BMI (n=84); Family history of allergy (n=283); Child birthweight category (n=7); Child BMI Z-scores -12M (n=90); Child BMI Z-scores- Yr4 (n=191); Child BMI Z-scores- Yr5 (n=184); Child BMI Z-scores- Yr6 (n=218); Duration of any breastfeeding (n=34); Duration of full breastfeeding (n=48).
Abbreviations: BF, breastfeeding; SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

Table 2. Association of breastfeeding (BF) exposure group with maternal-reports of child feeding and observational measures of eating behaviour from age 15 months to 6 years.

	N	Mean ± SD			Adjusted mean differences (95% CI)[c]		
		BF Low	BF Intermediate	BF High	BF Low	BF Intermediate	BF High
Maternal-report measures:							
Month 15							
Aware of infant's hunger & satiety cues (IFQ)[e]	858	3.3 ± 0.7	3.4 ± 0.6	3.3 ± 0.6	REF	0.1 (0.0, 0.2)[d]	0.0 (-0.2, 0.2)
Concern about infant overeating/ overweight (IFQ)[e]	838	1.0 ± 0.8	0.8 ± 0.7	0.9 ± 0.8	REF	-0.1 (-0.2, 0.0)	0.0 (-0.2, 0.2)
Year 3							
Difficulty in child feeding (PFQ)[e]	819	1.6 ± 0.9	1.7 ± 0.9	1.5 ± 0.7	REF	0.1 (-0.1, 0.2)	-0.2 (-0.4, 0.0)[d]
Concern about child overeating/ overweight (PFQ)[e]	813	0.9 ± 0.8	0.7 ± 0.6	0.7 ± 0.6	REF	-0.2 (-0.3, -0.1)[d]	-0.1 (-0.3, 0.1)
Satiety responsiveness (CEBQ, z-scores)	500	-0.09 ± 1.03	-0.03 ± 0.93	0.41 ± 1.03	REF	-0.03 (-0.24, 0.17)	0.24 (-0.07, 0.55)
Food fussiness (CEBQ, z-scores)	500	-0.06 ± 0.98	0.08 ± 1.02	-0.24 ± 1.04	REF	0.04 (-0.17, 0.25)	-0.38 (-0.70, -0.06)[d]
Year 6							
Satiety responsiveness (CEBQ, z-scores)	398	-0.05 ± 1.02	0.06 ± 0.98	-0.17 ± 0.85	REF	0.08 (-0.16, 0.33)	-0.11 (-0.51, 0.28)
Food fussiness (CEBQ, z-scores)	398	-0.05 ± 1.10	0.04 ± 0.99	-0.29 ± 0.73	REF	0.08 (-0.16, 0.32)	-0.27 (-0.66, 0.11)
Laboratory-based measures:							
Year 4.5							
Total lunch consumed (kcal)	445	275.8 ± 161.8	306.7 ± 152.5	315.2 ± 150.7	REF	16.6 (-18.4, 51.6)	11.8 (-39.1, 62.8)
Bite size (g/bite)	352	2.0 ± 1.3	1.9 ± 1.1	1.9 ± 1.3	REF	-0.1 (-0.4, 0.2)	-0.1 (-0.5, 0.3)
Chews per gram	352	11.0 ± 7.3	9.8 ± 5.5	10.4 ± 8.0	REF	-1.1 (-2.9, 0.6)	-0.6 (-3.2, 2.0)
Eating rate (g/min)	352	6.9 ± 3.4	6.9 ± 3.0	7.1 ± 3.5	REF	-0.2 (-1.0, 0.6)	0.3 (-0.9, 1.5)
Total meal duration (min)	352	20.9 ± 6.4	19.7 ± 6.7	20.9 ± 6.7	REF	-1.5 (-3.1, 0.1)	-0.8 (-3.3, 1.6)
EAH (yes/no intake)[a,b]	363	REF	1.23 (0.76, 1.97)	2.31 (1.07, 4.96)[d]	REF	1.03 (0.59, 1.79)	1.46 (0.62, 3.45)
Year 6							
Total lunch consumed (kcal)	421	196.2 ± 194.5	180.2 ± 120.3	212.6 ± 125.9	REF	-10.1 (-46.4, 26.1)	-3.2 (-58.5, 52.1)
Bite size (g/bite)	421	3.9 ± 3.3	3.7 ± 2.2	3.6 ± 1.2	REF	-0.1 (-0.6, 0.4)	-0.3 (-1.1, 0.4)
Chews per gram	421	5.2 ± 3.2	5.3 ± 3.0	4.3 ± 1.8	REF	0.3 (-0.4, 1.0)	-0.5 (-1.5, 0.5)
Eating rate (g/min)	421	13.4 ± 12.3	12.5 ± 7.7	13.8 ± 5.2	REF	0.2 (-1.7, 2.1)	1.4 (-1.4, 4.3)
Total meal duration (min)	421	10.8 ± 5.8	10.7 ± 6.2	10.7 ± 6.1	REF	-0.1 (-1.5, 1.3)	-1.4 (-3.5, 0.8)
EAH (yes/no intake)[a,b]	311	REF	1.27 (0.65, 2.51)	1.71 (0.55, 5.35)	REF	1.17 (0.51, 2.66)	1.70 (0.43, 6.78)

[a]Results are presented as odds ratio (95% CI).

[b]Models were additionally adjusted for total lunch consumed (kcal).
[c]Models adjusted for maternal age (years), ethnicity (Chinese, Malay, Indian), maternal education (secondary and below, technical school, tertiary), maternal pre-pregnancy BMI, child sex, child birthweight category (SGA, AGA, LGA).
[d]Values are P<0.05 compared to the reference group.
[e]Mean subscale scores ranged from 0 to 4.
Abbreviations: EAH, eating in the absence of hunger.